

ASSESSMENT OF THE CORE PROPERTIES OF A NEWLY DEVELOPED CORE BINDER WITH RESPECT TO UREA FORMALDEHYDE FURFURYL ALCOHOL (UFFA)-BENZENE SULPHONIC ACID (BSA) BINDER SYSTEM.

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ABSTRACT

The core properties of a newly developed core binder based on *Manihot esculenta*-cement combination was assessed and compared with an imported binder system commonly used in the foundry. The work investigated the properties of the newly developed binder system along side with the properties of UFFA-BSA binder system, which is an imported binder system. The core mixtures were prepared using the same sand; the north bank sand, with grain fineness number of 48.03 AFS, average grain size of 353.50 microns and clay content of 0.8%. The core properties of the newly developed binder system compared well with the core properties of the UFFA-BSA binder system, and can be a good replacement or alternative to the UFFA-BSA binder system. The newly developed binder system is more environmentally friendly than the UFFA-BSA binder system. The UFFA-BSA binder system has a dry compression strength of 4400kPa, and hygroscopy of 0.38%, while the newly developed binder system has a dry compression strength of 4200kPa, and hygroscopy of 0.33%.

KEYWORDS: Assessment, Core properties, Newly developed binder, and UFFA-BSA.

INTRODUCTION

Cold setting chemically bonded sands are now in use in the majority of the foundries (Morgan, 1973). Foundry sand binders for making core and mould can be divided into two main chemical classes: organic and inorganic. The last 65 years have seen the introduction of many excellent binder systems based on organic polymer chemistry. These organic systems have offered the primary advantage of improved shakeout capabilities over previous systems (Manning and Laitar, 1994).

Driven by today's environmental realities, an organic binder system which uses cement as the hardener was developed. The binder is non-toxic, not harmful to the hands, therefore eliminating emissions and odors associated with organic systems (Manning and Laitar, 1994, Archibald, 1993). The sand/ binder system is used for core making using existing foundry equipment, and can be used on any sand.

The curing is accomplished by allowing the core to stand for 10 hours. After acceptable curing the core can be removed and used immediately. Cores can be stored for extended periods through dry storage conditions or by leaving them in an airily open space. The resulting cores have acceptable strengths and can be readily handled.

The use of urea formaldehyde furfuryl alcohol (UFFA)-benzene sulphonic acid binder system normally gives rise to increase in production, because of the quick curing time of the cores made using the binder system (Goring, 1973). The binder is widely used in foundries as a cold setting chemical binder, it however has these drawbacks, increasing costs, shortages, injurious to the hands, has a strong odor, high emissions and therefore environmentally unfriendly. These drawbacks necessitated the development of an alternative binder system that would meet the strict regulations placed on the environment and binders used in the foundry (WTEC, 1997, Elwood, 1993, Geoffrey, 1993, Mckinley, *et al*, 1993, Moore and Mason, 1981, Adamovits and Barnett, 1993).

The objective of this paper is to compare the core properties of the newly developed organic binder system with that of the UFFA-BSA binder system.

MATERIALS AND METHODOLOGY

Materials

The materials used for the work included; urea formaldehyde furfuryl alcohol (UFFA), benzene sulphonic acid (BSA), north bank sand, sodium hydroxide, hydrochloric acid, water, *Manihot esculenta*, and cement, all sourced locally within Nigeria.

Equipment

The equipment used for the work included; set of sieves and sieve shaker, clay washer, stand and burette holder, pipette, furnace, desicator, speedy moisture tester, universal strength testing machine, mettler electronic weighing balance, electric permimeter, compactability tester, and shatter index device, others included, oven, green compression strength testing machine, and laboratory core mixer.

METHODOLOGY

The sand which was used for the preparation of core mixtures using the two binders was first characterized. The particle size distribution of the sand and the grain fineness number was determined using a sieve shaker and a nest of sieves made by George Fischer (+GF+). The clay content of the sand was determined using the clay washer made by Ridsdale and Co. Ltd. Middlesborough, England. The acid demand value of the sand was determined using the titration method.

Core Mixture Preparation

The laboratory core mixer, manufactured by Ridsdale and Co. Ltd. Middlesborough, England, serial No. 845 was used in the preparation of core mixtures for two binder systems. The same north bank sand was mixed with the two binders. The core mixture for the tests was first prepared using the newly developed binder system, after which core mixture containing UFFA-BSA binder system was prepared for similar tests.

Moisture Content Determination

A sample of each of the core mixture was removed for the moisture content determination using a speedy moisture tester, made by Thomas Ashworth and Co. Ltd. Burnley England, with model No. 2164.

Standard Specimen Preparation

The sand rammer made by Ridsdale and Co. Ltd. Middlesborough, England with a gross weight of 40kg was used for the preparation of standard 50 mm x 50 mm specimens to be used on the electric permimeter, universal strength testing machine, shatter index device, and green compression strength machine.

Permeability Test

The permeability of the test specimens made using the two binders was determined using electric permimeter made by Ridsdale, Co. Ltd. Middlesborough England with serial No. 872.

Green Shear Strength test

The green shear strength test of the test specimens was carried out using the universal strength testing machine made by Ridsdale and Co. Ltd. Middlesborough England with serial No. M-8415.

Green Compression Strength Test

The green compression strength test was carried out using the universal strength testing machine made by Ridsdale and Co. Ltd. Middlesborough England with serial No. M-8415.

Dry Compression Strength Test

The universal strength testing machine made by Ridsdale and Co. Ltd. Middlesborough- England, with serial No. M-8415 was used for the test.

Hygroscopy

The hygroscopy of the test specimen was investigated using digital weighing balance and a netted desicator. The specimens were left for 5 hours above water in a netted desicator before taking the final reading.

Loss on Ignition (LOI)

The loss on ignition was determined using a muffled furnace made by SCANDIA –OVNENAS Allerod, Denmark, with a model No. KHE1:170. The holding time was 2 hours and the ignition temperature was 925°C .

Compactability Test

The compactability test was carried out using the sand pouring hopper and the sand rammer, all made by Ridsdale and Co.Ltd. Middlesborough-England. The compactability was recorded in percentage after ramming for 5 times.

Refractoriness Test

The refractoriness was determined using an electric muffle furnace, which was heated to 800°C, and the sample specimen of the core mixture placed in the furnace was monitored at an interval of 25°C Up to 1000°C.

Shatter Index Test

The shatter index was determined using the shatter index device called the shatter index tester made by Ridsdale and Co.Ltd. Mddlesborough- England, TS 89EA. A standard DIN green sand test specimen was ejected from the specimen tube and fell 6ft. (1.83m) onto a steel anvil mounted in the centre of the 13.2 mm mesh British Standard Test Sieve.

RESULTS AND DISCUSSION

Results

The results of the work are presented in Tables 1 and 2

Table 1: Particle Size Distribution and Characterization of North Bank Sand.

S/no	ISO(B.S.410:1976)Micron	Sieve No.	Weight retained (g)	Percent weight retained	Cumulative weight	Product
1	1400	14	0.03	.03	.03	.00
2	1000	18	1.00	1.00	1.03	14.00
3	710	25	2.60	2.60	3.63	46.80
4	500	35	9.70	13.33	242.50	
5	355	45	25.60	25.60	38.93	896.00
6	250	60	34.20	34.20	73.13	1539.00
7	180	80	16.60	16.60	89.73	996.00
8	125	120	7.00	7.00	96.73	560.00
9	90	170	1.90	1.90	98.63	228.00
10	63	230	0.57	.57	99.20	96.90
11	-63 (pan)	-230	.80	.80	100.00	184.00
12						Σ4803.20
13	Grain Fineness No.	48.03 AFS				
14	Average Grain Size	353.50 microns				
15	Colour	Reddish Brown				
16	Grain shape	Angular and compound shape				
17	% Clay Content	0.80				
18	Acid demand value (ml)	12.60				

Table 2: Core Properties of the Newly Developed Binder System and Urea Formaldehyde Furfuryl Alcohol (UFFA) – Benzene Sulphonic Acid (BSA) Binder System.

S/no.	Core Properties	<i>Manihot esculenta</i> -cement binder system (the newly developed binder system)	UFFA-BSA Binder system
1	Amount of mixture for preparing standard specimen(50x50mm)	168 g	160 g
2	Permeability	250 AFS Perm units	300 AFS Perm units
3	Moisture content	5.8% (green condition)	0.4 %
4	Green shear strength	4.83kPa	8.27kPa
5	Green compression strength	17.58 kPa	10.34 kPa
6	Dry shear strength	273.73 kPa	
7	Dry compression strength	4200 kPa	4400 kPa
8	Hygroscopy	0.33%	0.38 %
9	LOI	6.25%	6.75%
10	Shatter index	60.20 %	
11	Refractoriness	No baking up to 1000°C	No baking up to 1000°C
12	Collapsibility	Very high with easy shakeout	Moderate collapsibility
13	Fumes	Less fumes	Greater fumes
14	Compactability	30.83 %	30.83 %
15	Sand fineness	All foundry sands	Sands with GFN above average
16	Odor	Mild	Strong odor with the smell of SO ₂
17	Reaction with core box	Sticks to core box when hardener is less than 1.5 %	Difficult to draw after setting.

DISCUSSION

Table 1, is the result of the particle size distribution and characterization of North Bank sand, the sand which was used in the determination of the core properties of the two binder systems. The result showed that the sand is 3-screen sand with the bulk of the sand on screen numbers, 45, 60, and 80. The bulk fraction of the sand which is 76.4% falls within the AFS specification for standard sand of sieve No.40-100 (Heine, *et al*, 2005). The sand has basic fraction of 76.4 % giving it a high degree of uniformity (Nwajagu, 2007).

The sand has a grain fineness number of 48.03 AFS, this is close to the range of 50-60 AFS commonly used in some foundries (Clark, *et al*, 1994). The sand has an average grain size of 353.50 microns, which is above the common used range of 220-250 microns (Brown, 1994). However, a look at the percent –retained column revealed that 36.40 % of the sand combined will have a grain size of 250 microns. According to Brown (1994) foundry sand usually fall into the range 150-400 microns, with 220-250 microns being the most commonly used.

The sand has a reddish brown colour. The shape of the sand is a mixture of both angular grains and compound shape grains. The clay content of the sand is 0.80 %, and the acid demand value of the sand is 12.60 ml at a pH value of 7.

According to Brown (1994) while average grain size and AFS grain fineness number are useful parameters, choice of sand should be based on particle size distribution. The size distribution of the sand affects the quality of the castings (Brown, 1994). Coarse –grained sands allow metal penetration into moulds and cores giving poor surface finish to the castings. Fine-grained sands yield better surface finish but need higher binder content and

the low permeability may cause gas defects in castings. The size spread should be 95% on 4 or 5 screens (Brown, 1994, Taylor, 1959).

The shape of the sand determines the packing and the final strength of the mould. Angular to compound shape sands are known to have high strength, but poor flowability (Heine,*et al*, 2005, Brown, 1994). According to Shrager (1961) the clay content of core sands is not to exceed 1%, except in exceptional cases. The sand is therefore within limits. The North Bank sand can be used for acid catalyzed core making process, since the acid demand value is less than 15ml (Brown, 1994, Rickards, 1982).

Table 2, is the core properties of the newly developed binder system and urea formaldehyde furfuryl alcohol (UFFA)-Benzene sulphonic acid (BSA) binder system. The newly developed binder system had a permeability of 250 perm units, while the UFFA-BSA binder system had a permeability of 300 AFS perm units, obviously the UFFA- BSA binder system has a higher permeability. Both binders however, have a permeability value, which is within the AFS specification of 80 AFS perm units and above (Odetundun, 1993). Table 2, shows that the moisture content of the newly developed binder is 5.8%, while that of the UFFA –BSA binder system is 0.4%. The newly developed binder requires a longer drying and curing time for the moisture content to go down. High moisture content in cores could give rise to casting defects during casting (Hoyt, 1994, Gilson, 1993). The newly developed binder system has green shear strength of 4.83kPa, while the UFFA-BSA binder system has green shear strength of 8.27 kPa. The newly developed binder system has a green compression strength of 17.58kPa, dry shear strength of 273.73kPa, dry compression strength of 4200kPa, hygroscopy of 0.33%, LOI of 6.25 %, shatter index of 60.2%, and compactability of 30.83%, while the UFFA-BSA binder system has a green compression strength of 10.34 kPa, dry compression strength of 4400 kPa, hygroscopy of 0.38%, LOI of 6.75% and compactability of 30.83%. Also looking at other properties of refractoriness, fumes generated, nature of sand required, odor emitted and reaction with core box, it can be seen that the newly developed binder system has some advantages over the UFFA-BSA binder system. They however, have the same compactability of 30.83% and the same refractoriness characteristic, where differences exists the margin is not so much, for instance the newly developed binder system has a dry compression strength of 4200kPa and the UFFA-BSA binder system has a dry compression strength of 4400kpa, a difference of 200kPa. The newly developed binder is however more environmentally friendly in terms of odor and emissions.

CONCLUSIONS

1. The above discussions have shown that the newly developed binder has good core properties, compare well with UFFA-BSA binder system and can be a good alternative to the UFFA-BSA binder system.
2. The newly developed binder is more environmentally friendly than the UFFA-BSA binder system
3. The same sand was used in the core properties determination, using the two binder systems.
4. The North Bank sand used was fully characterized
5. The sand had grain fineness number of 48.03 AFS, clay content of 0.8%, average grain size of 353.50 microns and acid demand value of 12ml.
6. The assessment of the core properties of the newly developed core binder has clearly shown that the binder can be used in place of the UFFA-BSA binder system.

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